Survey Report
VERMONT HIGH WATER MARK SURVEY

USGS Contract: G10PC00013
Task Order Number: G12PD00814

Prepared for:
UNITED STATES GEOLOGICAL SURVEY

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Hurricane Irene made landfall in the continental United States on August 27, 2011 in the Outer Banks of North Carolina as a Category 1 hurricane. The hurricane moved back into the Atlantic Ocean near southeastern Virginia and made another landfall in southeastern New Jersey on August 28 and continued up the eastern part of the United States. The storm impacted most of the coastal areas of the United States and caused significant flooding in Vermont, as well as other areas.

The United States Geological Survey (USGS) flagged high water mark (HWM) locations in Vermont months after the storm. USGS contracted with Dewberry to perform a survey of HWM locations across the state of Vermont as a result of the flooding from Hurricane Irene. The 1,174 HWMs are located within twelve counties of the state of Vermont to include Addison, Bennington, Caledonia, Chittenden, Franklin, Grande Isle, Orange, Orleans, Rutland, Washington, Windham, and Windsor.

The purpose of this project report is to detail the objectives of the HWM survey; benefits of obtaining HWM locations; field procedures, data derivations and adjustments; quality control procedures, and problems encountered in the field.

- **Section 1** HWM Survey Objectives
- **Section 2** HWM Benefits
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1. HWM SURVEY OBJECTIVES

The objective of this study is to provide a quantitative historical record of the Hurricane Irene flood event that will assist in carrying out the authorities under Title IV of the Stafford Act for major disaster declaration FEMA-4022-DR. This Interagency Agreement (IAA) between the Federal Emergency Management Agency (FEMA) and USGS consists of four major tasks related to this objective. The first is the task of surveying the located HWMs into a known base datum to document the extent and the depth of flooding. Dewberry, contracted through USGS, is performing this first task. The second is to characterize the flood event in relation to magnitude of floods over a selected range of exceedance probabilities at gaged sites. The third is to develop or update regionalized equations that can be used to determine the magnitude of floods over the selected exceedance probabilities at ungaged sites. The fourth is to develop flood inundation maps for selected study reaches along major flooding sources in Vermont that experienced greater than 100-year discharges and significant flood damages. These maps will be valuable for flood recovery efforts and carrying out the Hazard Mitigation Grant Program for the state of Vermont.

2. HWM BENEFITS

Characterizing the magnitude and frequency of floods at stream gages is important and will serve to aid flood mitigation efforts that will contribute to protection of life and property. Benefits of this study include:

- Flood profile analyses of the selected major flooding sources that help identify areas subject to flooding and aid government officials in the assessment and prioritization of where to concentrate efforts to lessen flood damages and to protect life and property.

- Regional flood-flow equations will be developed to replace existing equations by including the flood events that occurred in 2006, 2007, and 2010-11.
- Updated at-site and flood-flow equations together with the uncertainty estimates (confidence intervals) provide engineers and planners the best available values for design of bridges, culverts, road elevations and for floodplain planning and management.
- The results from the analysis proposed for this study will be incorporated into the National Streamflow Statistics (NSS) program, the National Streamflow Statistics database (StreamStatsDB), and the Web based National StreamStats program.
- The results of the study will help FEMA meet its goals for recovery following the 2011 flooding by delineating flood prone areas, guiding the issuance of flood insurance, and promoting effective flood-plain management.

3. PROJECT SUMMARY

Dewberry was contracted by the USGS to locate 1,174 HWM points for 12 counties in Vermont. Existing National Geodetic Survey (NGS) control points were located and surveyed to check the accuracy of the Real Time Kinematic (RTK)/GPS survey equipment. Final horizontal coordinates are referenced to Vermont State Plane Coordinate System, NAD83 (NSRS 2007), in feet. Final vertical elevations are referenced to NAVD 88 in feet, orthometric heights, using Geoid 09.

3.1. Point of Contact

Questions regarding the technical aspects of this report should be addressed to:

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3.2. Project Area

Figure 1, 2, and 3 depict the project area.

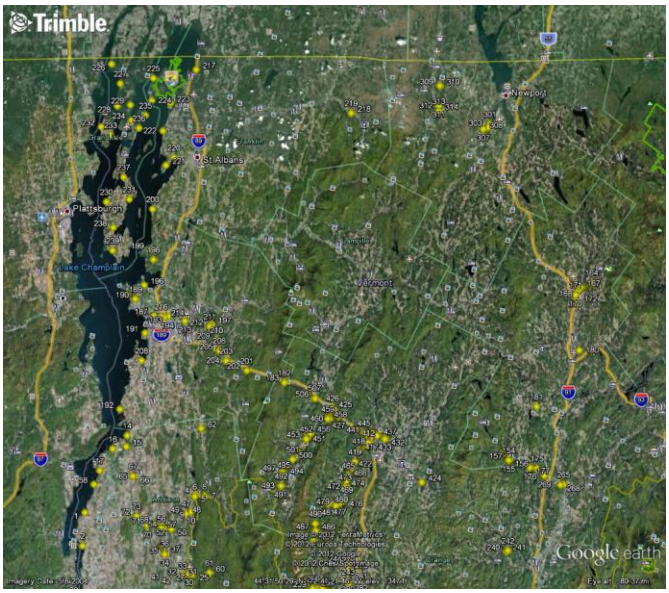

Figure 1: Project Area

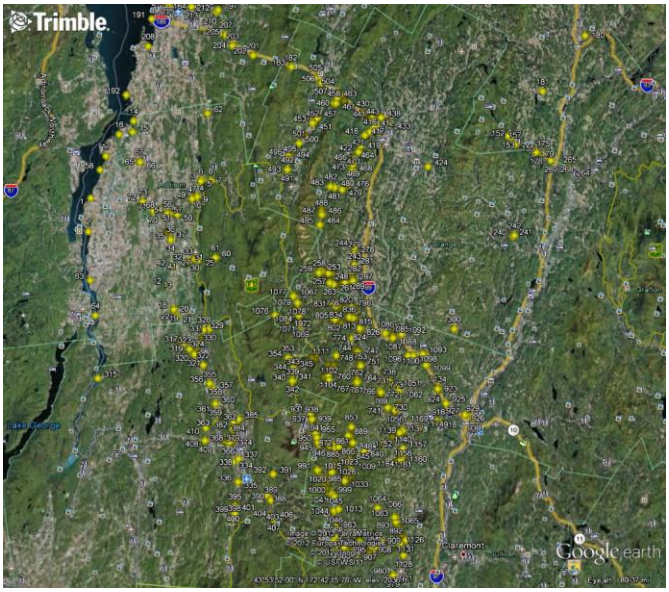

Figure 2: Project Area

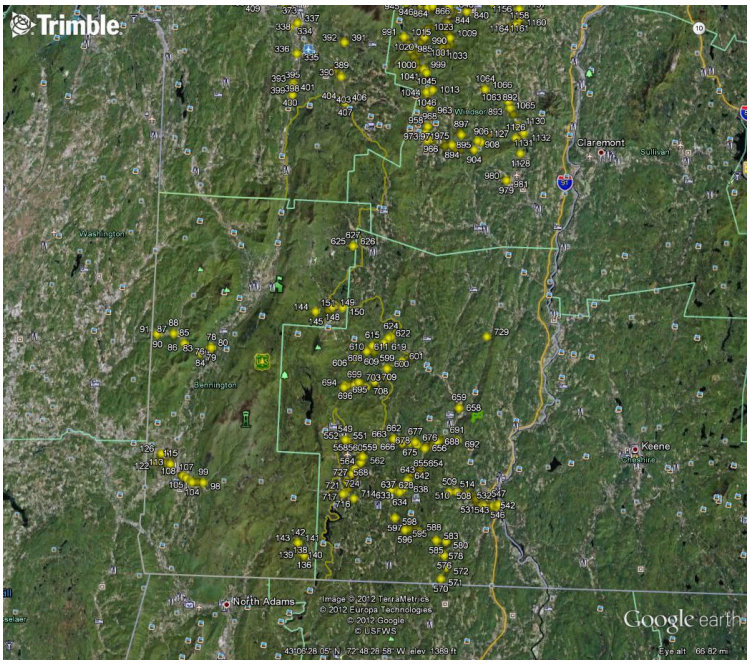

Figure 3: Project Area

4. PROJECT DETAILS

This section details the survey equipment, survey point detail, and network design.

4.1. Survey Equipment

In performing the GPS observations, Trimble R-8 GNSS receiver/antenna attached to a two meter fixed height pole with a Trimble TSC2 Data Collector to collect GPS raw data were used to perform the field surveys.

4.2. Survey Point Detail

A sketch was made for each location and a nail was set for each control point.

4.3. Network Design

The GPS survey was tied to a Real Time Network (RTN) managed by KeyNet GPS, Inc. The network is a series of "real-time" continuously operating, high precision GPS reference stations. All of the reference stations have been linked together using Trimble GPSNet software, creating a Virtual Reference Station System (VRS).

The Trimble NetR5 Reference Station is a multi-channel, multi-frequency Global Navigation Satellite System (GNSS) receiver designed for use as a stand-alone reference station, or as part of a GNSS infrastructure solution. Trimble R-Track technology in the NetR5 receiver supports the modernized GPS L2C and L5 signals as well as GLONASS L1/L2 signals.

5. FIELD SURVEY PROCEDURES AND ANALYSIS

Dewberry used Trimble R-8 GNSS receivers, which is a geodetic quality dual frequency GPS receiver, to collect data at each surveyed location. Each control point or HWM occupation which utilized the VRS

network was occupied for approximately three (3) minutes in duration and measured to 180 epochs. Each control point occupation which utilized OPUS was occupied between 18 and 20 minutes. Field GPS observations were detailed on internal documentation used by each surveyor. Seven (7) existing NGS monuments listed in the National Spatial Reference System database were located as an additional quality assurance /quality control method to check the accuracy of the VRS network. The results are in Table 1:

Table 1: VRS Accuracy Check

	Vermont SPCS NAD83/91 As Surveyed (ft)			Vermont SPCS NGVA88 Published (ft)			Differences (ft)		
NGS PT. ID	Northing(ft)	Easting(ft)	Elev.(ft)	Northing(ft)	Easting(ft)	Elev.(ft)	Δ N	Δ E	Δ Elev.
B95063	128741.88	1614161.55	439.16	N/A	N/A	439.09	N/A	N/A	0.07
B95064	127594.21	1616341.60	420.47	N/A	N/A	420.42	N/A	N/A	0.05
S 0145 2 SA	326540.26	1586571.17	1009.13	N/A	N/A	1009.14	N/A	N/A	0.01
PINNEY HOLLOW	386405.47	1586625.41	1103.21	386405.64	1586625.56	1103.00	0.17	0.15	0.21
B94038	397302.87	1597452.39	870.57	N/A	N/A	870.70	N/A	N/A	0.13
B94033	400273.62	1584588.68	972.34	N/A	N/A	972.59	N/A	N/A	0.25
H12	496361.04	1455120.58	355.70	496361.06	1455120.54	355.49	0.02	0.04	0.21

The above results indicate that the VRS network is providing positional values within the parameters for this survey.

5.1. Adjustment

The survey data was collected using Virtual Reference Stations (VRS) methodology within a Virtual Reference System (VRS). The system is designed to provide a true Network RTK performance, the RTKNet software enables high-accuracy positioning in real time across a geographic region. The RTKNet software package uses real-time data streams from the GPSNet system user and generates correction models for high-accuracy RTK GPS corrections throughout the network. Therefore, corrections were applied to the points as they were being collected, thus negating the need for a post process adjustment.

5.2. Data Processing Procedures

After field data was collected, the information was downloaded from the data collectors into the office software. The software program used is called Trimble Geomatics Office (TGO). Downloaded data was run through the TGO program to obtain the following reports: points report, point comparison report, and a point detail report. The reports were reviewed for point accuracy and precision. After review of the point data, an "ASCII" or "txt" file, which is the industry standard, was created. Point files were then loaded into our CADD program (Carlson Survey 2010) to make a visual check of the point data (HWM Number, Coordinates, Elevation and Description).

5.3. Unrecoverable Mark Search Efforts

The HWM's were flagged by the USGS after Hurricane Irene between August and October of 2011. Since this time, HWMs were found to be missing or unrecoverable during the Dewberry survey. In discussions with USGS, Dewberry and USGS agreed that the surveyors would spend 15-30 minutes searching for the marks. If the mark was not found, the surveyors detailed the reason in the Microsoft Excel spreadsheet.

5.4. High Water Mark Crew Procedure

Each crew contacted their respective survey coordinator at the end of the day to check-in, discuss any problems, confirm that each day's marks, pictures, and document sheets were reviewed for missing info, etc.

Each crew was responsible to survey the marks assigned to them. Survey coordinators were responsible for assisting in the location of marks where needed and for checking NGS Control Points.

The survey crews were provided HWM location information on a spreadsheet provided by USGS. The information on the spreadsheet including the pictures, coordinates, river or area, bank, location relative to structure or water, position, road name, marked by (i.e., nail w/flagging) and comments assisted in finding the HWM locations.

Each mark was located horizontally as accurately as possible given the type of mark (i.e., mark could be a tree with nail/flagging, tape or paint on a structure, etc). The vertical elevation of the HWM was recorded (i.e., if the nail is in a tree 5 feet from the ground you will locate the nail not the ground). Each mark had two pictures taken; one up close, and one to show background. The unique HWM ID was shown in the pictures large enough to be visible.

For each mark, the surveyors filled out internal documentation called a "High Water Mark Document Report" that included a sketch of the area and any survey comments. These survey comments were transposed to the Microsoft Excel spreadsheet delivered as part of this project.

Two Control Points were set if a mark could not be located directly with GPS. A pk nail or 60-P nail is adequate with flagging, no need for stakes at each point. Each crew was given a range of point numbers to use for control points.

If the HWMs were located on private property, the surveyors attempted to notify the landowner when possible that they were entering their property and for what purpose. Each landowner contacted was given the "Landowner Letter". The utmost care was taken on private property and no trees or vegetation was cut.

5.5. Equipment

The surveyors had specific personal protective equipment requirements which included Hi-Viz vests, boots, and long pants. Hardhats and safety glasses were used as site conditions warranted. Truck mounted amber warning lights and cone(s) were used when stopped at each point.

Each survey vehicle had the following:

- Laptop for downloading pictures, OPUS sessions, etc.
- Vehicle GPS (Garmin, TomTom or equivalent) for driving directions and general location
- Camera w/memory card(s)
- Two (2) GPS Receiver(s) (with collector)
- Normal survey field crew supplies, stakes, nails, flagging, clipboard, markers, etc.
- Converter for charging batteries in the vehicle
- Instrument legs, bi-pods, etc.

- Robotic or Conventional Total Station instrument

6. QUALITY CONTROL

In addition to the survey quality control efforts detailed Field Survey Procedures and Analysis section, quality control checks were performed using geospatial data. The quality control checks and results included the following:

- Dewberry reviewed the data after the initial survey field visit and made two additional visits to Vermont to correct a receiver issue, collect additional photos, and to search for unfound marks.
- A surface was developed from the HWM elevations to determine if there were any visible spikes and/or dips that needed to be reviewed. This check found two elevations that were provided in meters instead of feet. The elevations were converted to feet and this issue was resolved.
- A comparison was performed between the coordinates of the USGS provided spreadsheet with the HWM locations and the survey coordinates. If significant discrepancies were found, the horizontal coordinates were investigated further. This check found a few coordinates that had the incorrect HWM identification number and was updated to reflect the correct number.
- The HWM elevations were compared with the elevations from a 30 meter Digital Elevation Model (DEM) available for Vermont. A 30 meter DEM could have a vertical error of up to 50 feet. With this level of vertical error, this check was primarily performed to make sure the survey HWM elevations were close to the 30 meter DEMs. If better elevation data were available, we would have been able to make sure the survey elevations were above the ground elevations and verify that the survey HWM elevations minus the ground elevations matched the measured HWM data from USGS.

7. FIELD SURVEY PROBLEMS

The HWM data was flagged by USGS approximately one year ago. The surveyors were unable to locate 304 points as a result (26% of the 1174 marks). The reason that the surveyors were unable to locate the points is documented in the spreadsheet, but a summary is provided in this document. The majority of points were unrecoverable because the surveyors were unable to locate the points within a 15-30 minute search once they were in the general area of the point. There were points that were destroyed, missing due to erosion, washed away, unable to access, and removed. Table 2 summarizes the number of points found, not found, and reason not found.

Table 2: Unrecoverable HWMs

HWM Located?	Reason	Number
Yes	Found	870
Not Found	Destroyed	55
Not Found	Indirect Discharge Measurement Taken by USGS nearby	1
Not Found	Missing/Unable to Locate	234
Not Found	No Access	8
Not Found	Overgrowth/Debris	6